

California's Proposal for 2002-2004 NOAA Coastal Fellowship

DEVELOPMENT OF A GIS-BASED PREDICTIVE TOOL FOR COASTAL BLUFF EROSION

1. Introduction

Some 85% of California's coast is actively eroding. Not only does this erosion threaten existing development, but it also creates a coastal management challenge in regulating the development of existing legal lots. Establishing appropriate erosion mitigation strategies is an important coastal zone management priority. In fact, the California Coastal Act requires that erosion protection in the form of coastal armoring "shall be permitted when required to serve coastal-dependent uses or to protect existing structures or public beaches in danger from erosion." Armoring is, however, of concern because it inevitably fixes the landward edge of a beach or coastal wetland, arresting the natural landward movement of these habitats as a result of sea level rise. This inevitably results in the loss of these habitats. Further, coastal armoring can reduce the contribution of sand from coastal bluffs to the beach environment, and has potential impacts to biological resources, aesthetic values, and public access. Although coastal erosion data exist for the state, there has been no attempt to organize these data into a useful tool for coastal zone management. Such a tool, through which areas at high risk can be identified, would be of great benefit to land-use planning entities and decision makers. By identifying erosion hazards, appropriate development setbacks may be adopted, and future armoring requirements can be reduced.

Coastal erosion in California takes the form of both beach and coastal bluff erosion. Whereas beach erosion, the primary mode of coastal erosion in much of the nation, reflects a complex interplay between sediment supply, sea level rise, and littoral cell transport, coastal bluff erosion appears to be more closely related to such geologic factors as bedrock strength, fracture spacing, tectonic uplift/subsidence, and the relative proportions of bedrock and marine terrace deposits in heterogeneous coastal bluffs. The proposed study will search for correlations between coastal bluff erosion rates and the geologic characteristics of bluffs (e.g., bedrock type, proportion of marine terrace deposits, fracture spacing, tectonic uplift/subsidence rate). Such correlations, together with an inventory of existing coastal armoring, will be used to construct a GIS-based predictive tool to help identify current and future bluff erosion hotspots. Such a tool will help policy makers to approach coastal erosion problems on a regional, rather than site-specific basis. The database used to develop this tool will be drawn from the portion of the California coast adjacent to the Monterey Bay National Marine Sanctuary (MBNMS), but will later be expanded to include all of the California Coast.

Immediate benefits to the State include the establishment of a database compiling erosion rates and existing coastal armoring for a diverse section of the California coast. Simply compiling such a database will be useful in coastal zone management in a num-

ber of ways. First, by identifying unarmored areas with high erosion rates, requests for future armoring can be anticipated. Anticipation of future coastal armoring requests before a crisis situation develops allows time for better consideration of alternative methods of shoreline protection, or even alternatives to armoring. Second, during the periodic review of Local Coastal Programs (the implementation of the California Coastal Act at the local government level), knowledge of areas that are currently armored and areas that are experiencing high erosion rates allows for improvement of land use plan policies and implement measures which could include, for example, the establishment of realistic construction setbacks. Third, the database will allow technical staff of the California Coastal Commission to evaluate the data submitted in support of permit applications by comparing the submitted erosion rate data with those predicted on the basis of comparison to similar geologic environments. Fourth, the coastal erosion and armoring databases can be combined with marine databases showing nearshore hard and soft bottom types and biological habitats to help assess resources at risk from coastal erosion and armoring. Finally, staff of the Monterey Bay National Marine Sanctuary have indicated that identification of different erosion regimes along the coastline fronting the MBNMS will allow for better comprehensive review of future armoring within MBNMS waters. This database will be an important step towards developing a coordinated regional approach to regulating coastal armoring, as well as strengthening the current case-by-case permit review used by state and federal agencies.

We anticipate, however, that the study will result not only in a comprehensive database of bluff erosion rates and armoring data for a portion of the California coast, but also will yield a predictive tool that can be used to identify areas of high erosion for which no erosion rate data are available. By searching for correlations between geologic characteristics of coastal bluffs and erosion rates, areas that might be experiencing rapid erosion can be quantitatively assessed. Thus, the GIS can be queried to show where areas of high erosion might be anticipated, allowing it to serve as a predictive tool, in addition a simple coastal erosion and armoring database. This predictive tool will be of use in permit review, land use planning, and development of shoreline erosion policy.

Although no comprehensive database on coastal armoring and erosion exists for any portion of the California coast, we have chosen the section embraced by the Monterey Bay National Marine Sanctuary as the site for this pilot project. This 276 mile long section of the coast represents approximately 25% of the California coastline and contains great variability in coastal bluff morphology, geology, erosion rate, and human development pressure. In addition, the region has the highest diversity of marine species in the temperate regions of the world, and has been recognized by Congress as an area needing special protection. The coastal resources and accessible beaches in the area are a key component in making tourism a two billion dollar industry on the central California coast, second only to agriculture in the region's economy. All of these scientific and socioeconomic factors make the region an ideal place to conduct this pilot study. That portion of the MBNMS lying within Santa Cruz County will be examined first because the wealth of existing data in that area will facilitate the development and validation of

the tool before it is extended to the rest of the MBNMS. We anticipate that by the end of the fellowship period a robust database encompassing all of the MBNMS will be developed. This pilot database will then be extended through successive efforts at the Coastal Commission to the remaining portions of the California coast.

This project will be undertaken in collaboration with a number of other institutions. Faculty and students at the University of California, Santa Cruz will provide expertise, assistance, and facilities for evaluation of geologic and coastal erosion rate data. Faculty and students at the Monterey Bay campus of the California State University will assist with gathering inventory data on existing coastal armoring. The County of Santa Cruz has graciously agreed to license their GIS-based data layers to serve as a framework on which to assemble our data; staff from their Planning Department will work closely with the Fellow to establish the GIS framework for this project. Finally, staff of the Monterey Bay National Marine Sanctuary, the planning departments of the other counties (San Luis Obispo, Monterey, and San Mateo) with coastline bordering the MBNMS, the California State Coastal Conservancy, and the Western Region Coastal and Marine Geology Team of the U.S. Geological Survey will provide review and advice on ways to make the database/predictive tool as useful as possible for the needs of those agencies.

2) Goals and Objectives

- To develop a database cataloging coastal erosion rates for areas of the California Coast within the Monterey Bay National Marine Sanctuary, San Luis Obispo, Santa Cruz, Monterey, and San Mateo counties.
- To develop a database cataloging coastal armoring for areas of the California Coast within the Monterey Bay National Marine Sanctuary
- To develop, from the above data and from literature-based data on geologic makeup and structure, a GIS-based database and predictive tool for evaluating potential coastal erosion hotspots for areas of the California Coast within the Monterey Bay National Marine Sanctuary
- To provide a GIS-based framework by which the above databases and predictive structure can be expanded to the rest of the California coast
- To provide to the State a tool for identifying potential bluff erosion hotspots for use in land-use planning and coastal zone management
- To provide a learning environment for the Fellow, in which s/he will develop an expertise in coastal erosion and GIS database development, and will be exposed to a wide range of coastal zone management issues including hazards, public access, recreation, visual, and environmentally sensitive areas.

3) Milestones and Outcomes

Activities (activities within each cell are concurrent)	Deadline for completion
<ul style="list-style-type: none"> • Orient to the Commission • Develop contacts with local governments, academic partners, and resource agencies • Become familiar with the California Coast • Become familiar with existing data and resources 	1 Nov 2002 (4 mos)
<ul style="list-style-type: none"> • Develop a set of criteria for evaluating coastal erosion rate data. • Develop a set of geologic parameters that may be correlated with coastal erosion 	1 Jan 2003 (2 mos)
<ul style="list-style-type: none"> • Develop familiarity with GIS and database management tools available (programs, existing data layers, existing databases) 	1 Mar 2003 (2 mos)
<ul style="list-style-type: none"> • Develop a GIS-based data structure to house the needed content; construct logic framework for using these data as an erosion prediction tool. 	1 May 2003 (2 mos)
<ul style="list-style-type: none"> • Identify, inventory, and compile existing geologic data from literature, consultant reports, and local stakeholders, beginning with Santa Cruz County. • Identify, inventory, and compile existing coastal erosion data from literature, consultant reports, and local stakeholders, beginning with Santa Cruz County. • Identify, inventory, and compile existing coastal armoring data from Commission and Santa Cruz County databases, and from databases compiled by CSUMB students. 	1 Oct 2003 (5 mos)
<ul style="list-style-type: none"> • Expand database to remainder of MBNMS, counties of San Luis Obispo, Monterey, and San Mateo 	1 Feb 2004 (4 mos)
<ul style="list-style-type: none"> • Test and validate the GIS database as a predictive tool 	1 Apr 2004 (2 mos)
<ul style="list-style-type: none"> • Conduct two to four training seminars to facilitate Commission staff's and local coastal zone planning agencies' use of database as an erosion prediction tool 	1 June 2004 (2 mos)
<ul style="list-style-type: none"> • Contingency; as time permits, expand database to other parts of California Coast 	1 Jun 2004 (2 mos)

Specific anticipated outcomes of benefit to the State CZMA program include:

- 1) Inventory of coastal erosion rates adjacent to the Monterey Bay National Marine Sanctuary; counties of San Louis Obispo, Monterey, Santa Cruz and San Mateo.
- 2) Inventory of existing coastal armoring adjacent to the Monterey Bay National Marine Sanctuary
- 3) Creation of a pilot GIS-based erosion prediction tool for the portion of the coast adjacent to the Monterey Bay National Marine Sanctuary
- 4) A framework for expanding these databases and tools to the entire California coast.
- 5) Use of this database and predictive tool in periodic review of policies and implementing measures contained in the Local Coastal Plans; most immediately, the Monterey County Local Coastal Plan.

Specific anticipated outcomes of benefit to the Fellow include:

- 1) Exposure to the coastal zone management operations the State of California; a familiarization with important policy issues in coastal zone planning.
- 2) Experience in communicating scientific information with community stakeholders and policy makers to aid in decision-making processes.
- 3) Develop expertise in bluff erosion processes and their correlation with local geology
- 4) Develop expertise in management of GIS databases and in using such systems as predictive tools

4) Project Description

Orientation (4 months)

The first phase of the Fellowship will be a period of orientation and planning for the Fellow. The Fellow will spend approximately the first four months becoming familiar with the California Coastal Act, the Commission and its staff, and the policy challenges that the Commission faces. During this period the Fellow also will have the opportunity to meet and consult with stakeholders at the federal, state, and local level in order to learn what resources are available and to evaluate needs of the various entities. The Fellow will also be introduced to faculty and staff at the academic institutions supporting this project, especially the Institute of Marine Sciences at the University of California, Santa Cruz, and the Institute of GIS and Spatial Analysis at California State University, Monterey Bay. Finally, several field trips and site visits will help to familiarize the Fellow with the central California coast and its geology.

Establishment of data types and standards for evaluating data quality (2 months)

Following the orientation period, the Fellow will work with existing coastal erosion rate data gleaned from a variety of sources—government studies, peer-reviewed publications, and data in the reports of private consultants. The latter data source constitutes a sort of “gray literature” that the Commission is privy to in its permit review process. This wealth of data typically is overlooked in assembling evaluations of coastal erosion, and by including these data the resulting database will have a much broader base than has been used in previous studies. Evaluating the quality of these diverse types of data and weighting them accordingly will be a prime challenge to assembling the coastal erosion rate database. We anticipate that the Fellow will take several months to develop a data quality ranking system. Also during this time, the Fellow will review published literature and confer with coastal erosion experts in the supporting organizations to develop a set of geologic characteristics that will be correlated with the erosion rate data. Preliminary review indicates that rock type, fracture spacing, makeup of heterogeneous

bluffs, and tectonic uplift/subsidence rate are especially promising geologic parameters to investigate.

Development of GIS framework and logical algorithm for predictive tool (4 months)

The next phase of the project is the development of a GIS framework for the inventory data that will be used to develop the database as a predictive tool. This period may entail familiarization with the GIS and database tools at the Fellow's disposal (principally ArcGIS® and Microsoft Access®), depending on the Fellow's background. This GIS framework will be designed to take advantage of existing data layers, including a statewide coastline base map developed by a previous NOAA Coastal Fellow (Melanie Coyne). The Commission currently is finalizing a licensing agreement with the County of Santa Cruz to make available to the Commission and to the Fellow an extensive digital database of coastal features (including parcel boundaries, soil maps, and rectified digital aerial photos). In addition, the Commission recently (June 2001) had flown a set of aerial photographs for the coast of the entire state; these data also will be available to serve as a photographic base for the proposed study. Finally, inventories of present coastal armoring exist in at least two forms. The Monterey Bay Regional Cumulative Assessment Project (ReCAP), completed by the Commission in 1995, includes data on structures permitted by the Commission between 1977 and 1995. Structures constructed prior to the establishment of the Commission, and those constructed illegally, are more poorly known. In order to better understand the totality of existing coastal armoring, the Commission has recently entered into a program with the Institute of GIS and Spatial Analysis at California State University, Monterey Bay, through which students will, as part of the University's Service Learning Program, help to inventory existing structures as they learn about GIS. These data also will be available to the Fellow for inclusion into the database, and may be of great utility in developing the database as a predictive tool for establishing coastal bluff erosion hotspots.

The Fellow will next develop a structure to accommodate the types of coastal erosion and geologic data that s/he has determined will be part of the database. The strategy to be employed to explore correlations between these types of data will then be established. Finally, the Fellow will develop the logical algorithm to be used to extend these correlations to allow the database to function as a predictive tool. This last step will need to be refined as the data are entered into the database and the important correlations between geologic character and erosion rate are established.

Data acquisition (9 months)

The next phase of the project will be to compile data and assemble the database whose structure was established in the previous phase. Data acquisition will be geographically based. Because a wealth of quality data concerning coastal erosion rate, geologic character, and coastal armoring already exists for Santa Cruz County, this portion of the MBNMS will be tackled first. By assembling data from this section of coast, the structures and logic established above can be tested fully.

Following integration of this relatively easily accessed data, the database will be extended to include the remainder of the MBNMS. By expanding the database to include areas marked by vastly different geologic character, erosion rates, and development pressures, the correlations established for Santa Cruz County can be tested and refined.

Finally, as time permits, data for other portions of the California coast will be included. Logical areas to tackle first include San Diego County, the site of some of the Commission's most challenging erosion-related policy decisions, and Humboldt County, where some of the State's highest long-term coastal erosion rates have been documented.

Evaluation, testing, and validation (2 months)

Evaluation and testing of the database will be an ongoing aspect of the data acquisition stage. Validation of the use of the database as a predictive tool will, however, require additional work. Validation will be through prediction of coastal erosion rates of areas where erosion rate data were not used to establish correlations between erosion rate and geologic character. These areas may be deliberately excluded from the correlation analysis in order to allow for later validation, or they may be areas for which new high-quality data become available during the course of the Fellowship. The degree to which the logical algorithm for predicting coastal erosion rates is successful will be a test of the tool. Required refinement of the algorithm, which may necessitate the integration of new types of information, will be assessed at this stage.

Dissemination (2 months)

Near the end of the Fellowship project, the Fellow will help to develop a transition to a system to be maintained by Commission staff. It is anticipated that the Commission's staff geologist, Dr. Mark Johnsson, will take over primary responsibility for maintenance of the database. Entry of data for the remainder of the California coast into the database will, however, be facilitated by developing an easy system for recording geologic, erosion rate, and armoring data available to Commission staff. The Fellow will develop this system, probably concurrently with data acquisition, and will train Commission staff in its use through a series of training sessions at the headquarters and regional offices.

The use of the database as a predictive tool by stakeholders inside and outside of the Commission will be through access to an online version of the database (probably through the use of the Commission's web site and ArcIMS®, which can be used to undertake GIS-style inquiry over the web). The Fellow will train stakeholders in such use through meetings in Santa Cruz and Monterey. The Fellow also will work with the GIS staff of the Monterey Bay National Marine Sanctuary to allow for the integration of existing marine databases showing nearshore hard and soft bottom types and biological habitats to help assess resources at risk from coastal erosion and armoring

5) Fellow Mentoring .

The Fellow will reside in the Headquarters Office of the Coastal Commission in San Francisco. The Commission's staff geologist, Dr. Mark Johnsson, will be the formally designated mentor and will be available on a daily basis for direction and consultation. Before joining the Commission, Dr. Johnsson taught for seven years at Bryn Mawr College and Stanford University, where he advised numerous graduate and undergraduate students in research projects. This experience will stand him in good stead in serving as an advisor and mentor. The Fellow will be an integral member of the Technical Services Unit, which serves the Commission and its staff in a technical advisory role, and will work closely with the Commission's staff engineer, GIS-specialist, and mapping unit. Site visits will familiarize the Fellow with the varied geologic conditions along the California coast, and with coastal zone management issues as experienced by the staff at the Commission's six regional offices. The Fellow also will work with senior policy staff at both the Coastal Commission and other departments within the California Resources Agency in order to understand the policy and planning uses to which the database and prediction tool will be applied.

In addition, the Fellow will meet and confer with stakeholders from local government, resource agencies, and environmental organizations and in so doing will come to understand their mandates and information needs. In particular, the Fellow will work closely with staff of the County of Santa Cruz planning department in establishing the initial pilot database and with staff of the Monterey Bay National Marine Sanctuary. Finally, the Fellow will work with Dr. Gary Griggs at the University of California, Santa Cruz, one of the foremost authorities on erosion along the California coast.

6) The California Coastal Commission

The California Coastal Commission was established as a result of a 1972 voter initiative creating a temporary commission to develop a statewide plan to protect the resources of California's coastal zone. In 1976, the state legislature adopted most of the policies of the resulting plan and established the Commission as a permanent state agency with a mandate that includes the protection and enhancement of wetlands and other environmentally sensitive habitats in the coastal zone. The Commission comprehensively manages coastal resources using planning, permitting and non-regulatory mechanisms, in cooperation with federal, state and local agencies. Along with federal consistency review authority, the Commission's primary mechanism for implementing its management plans for the coast is the coastal development permit program. These permits are issued either directly by the Commission or by a local government to which this authority has been delegated through a certified Local Coastal Program (LCP).

7) Project Partners

Monterey Bay National Marine Sanctuary is a federally designated protected area covering 5000 square miles of marine waters, administered by the National Oceanic and Atmospheric Administration. Its mandates are to enhance and protect the region's marine resources, conduct research and education, and foster multiple uses of the Sanctu-

ary which are compatible with the primary goal of resource protection. This project will strengthen the Sanctuary's current review of individual coastal armoring permit proposals, and more importantly, provide the basis for developing with the Coastal Commission and other agencies a regional approach to coastal armoring which will reduce cumulative impacts to Sanctuary resources. Sanctuary staff will assist by working with Dr. Johnsson and the Fellow to ensure that the database meets their needs, and will also provide access to and interpretation of their existing bottom habitat and biological databases.

The California State Coastal Conservancy (SCC) has been planning for the development of a statewide Sediment Management Master Plan in conjunction with the interagency Coastal Sediment Management Workgroup. The geologic character, erosion rate and armoring information developed through this fellowship project will serve as important framework data layers for the Master Plan's GIS database.

In addition to these partners, this project will be undertaken in collaboration with the local planning offices of the Counties of Santa Cruz, Monterey, San Mateo and San Luis Obispo. The project also will make use of expertise and facilities at the Institute of Marine Sciences at the University of California, Santa Cruz, and the Institute of GIS and Spatial Analysis at California State University, Monterey Bay. Finally, resources and personnel from the Western Region Coastal and Marine Geology Team at the U.S. Geological Survey, located in Santa Cruz, will be available to assist with the project.

7) Cost Share Description

The \$15,000 cost-sharing element of this proposal will be funded from the Coastal Commission's regular personnel budget, provided from the State's general fund. In addition, the State will provide the Fellow with all pertinent work facilities, computer, and will bear in-kind costs associated with support of the Fellow as follows:

	CSC	California	Total
Personnel	\$60,000	\$15,000	\$75,000
Mentoring	0	\$25,000	\$25,000
Facilities operations	0	\$36,000	\$36,000
Travel within California	0	\$5,000	\$5,000
Equipment	0	\$4,000	\$4,000
Training	0	\$1,000	\$1,000
Software and data processing	0	\$4,000	\$4,000
Printing	0	\$2,000	\$2,000
Telephone and communications	0	\$4,000	\$4,000
Postage	0	\$2,000	\$2,000
General supplies	0	\$4,000	\$4,000
TOTAL FOR 2 YEARS	\$60,000	\$101,000	\$157,000